Journal of the American College of Cardiology
Vol. 46, No. 7, 2005

Published by Elsevier Inc.
ISSN 0735-1097/05/$30.00
doi:10.1016/j.jacc.2005.07.009

Achieving Door-to-Balloon Times That Meet Quality Guidelines

How Do Successful Hospitals Do It?

Elizabeth H. Bradley, PhD,* Sarah A. Roumanis, RN,# Martha J. Radford, MD, FACC,†# Tashonna R. Webster, MPH,* Robert L. McNamara, MD, MHS,† Jennifer A. Mattera, MPH,# Barbara A. Barton, RN,# David N. Berg, PhD,‡ Edward L. Portnay, MD,† Harry Moscovitz, MD,§ Janet Parkosewich, RN, MSN,** Eric S. Holmboe, MD,‖ Martha Blaney, PharmD,†† Harlan M. Krumholz, MD, SM, FACC*†¶#

New Haven, Connecticut; and South San Francisco, California

OBJECTIVES We sought to recommend an approach for minimizing preventable delays in door-to-balloon time on the basis of experiences in top-performing hospitals nationally.

BACKGROUND Prompt percutaneous coronary intervention (PCI) for patients with ST-segment elevation myocardial infarction (STEMI) significantly reduces mortality and morbidity; however, door-to-balloon times often exceed the 90-min guideline set forth by the American College of Cardiology (ACC) and the American Heart Association (AHA).

METHODS We conducted a qualitative study using in-depth interviews (n = 122) of hospital staff at hospitals (n = 11) selected as top performers based on data from the National Registry of Myocardial Infarction from January 2001 to December 2002. We used the constant comparative method of qualitative data analysis to synthesize best practices across the hospitals.

RESULTS Top performers were those with median door-to-balloon times of ≤90 min for their most recent 50 PCI cases through December 2002 and the greatest improvement in median door-to-balloon times during the preceding four-year period 1999 to 2002. Several critical innovations are described, including use of pre-hospital electrocardiograms (ECGs) to activate the catheterization laboratory, allowing emergency physicians to activate the catheterization laboratory, and substantial interdisciplinary collaboration throughout the process. In the ideal approach, door-to-balloon time is 60 min for patients transported by paramedics with a pre-hospital ECG and 80 min for patients who arrive without paramedic transport and a pre-hospital ECG.

CONCLUSIONS Hospitals can achieve the recommended ACC/AHA guidelines for door-to-balloon time with specific process design efforts. However, the recommended best practices involve extensive interdisciplinary collaboration and will likely require explicit strategies for overcoming barriers to organizational change. (J Am Coll Cardiol 2005;46:1236–41) © 2005 by the American College of Cardiology Foundation

Despite evidence that prompt percutaneous coronary intervention (PCI) for patients with ST-segment elevation myocardial infarction (STEMI) significantly reduces mortality and morbidity (1,2), in many cases door-to-balloon time is longer than the 90-min guideline (3–5) set forth by the American College of Cardiology (ACC) and the American Heart Association (AHA) (6). Delays can occur in several parts of the process between patient hospital arrival and balloon inflation, including time to obtain an electrocardiogram (ECG), time from ECG to diagnosis of STEMI, time to transfer patients from the emergency department (ED) to the catheterization laboratory, and time in opening the arteries with PCI. Although variation in this complex process is inevitable, some delays may be preventable through process redesign. The goal of this study was to suggest best practices for achieving outstanding door-to-balloon times on the basis of approaches of top-performing hospitals: those with median door-to-balloon times of 90 min or less and with recent marked improvement. To illustrate these best practices, we developed a flow chart describing an approach for minimizing preventable delays. We also present Gantt charts (7) to summarize graphically the major steps in the process and target time intervals for each.

From the *Department of Epidemiology and Public Health, †Section of Cardiovascular Medicine, Department of Medicine, ‡Department of Psychiatry, §Section of Emergency Medicine, Department of Surgery, ‖Department of Medicine, ¶Robert Wood Johnson Clinical Scholars Program, Yale University School of Medicine, New Haven, Connecticut; #Yale New Haven Health Center for Outcomes Research and Evaluation, New Haven, Connecticut; **Yale New Haven Hospital and Yale University School of Nursing, New Haven, Connecticut; ††Genentech Inc., South San Francisco, California. Dr. Holmboe is currently affiliated with the American Board of Internal Medicine, Philadelphia, Pennsylvania. This research was supported by the National Heart, Lung, and Blood Institute (NHLBI), under grant #R01HL072575. Dr. Bradley is supported by the Patrick and Catherine Weldon Donaghue Medical Research Foundation (# 02-102) and a grant from the Claude D. Pepper Older Americans Independence Center at Yale (#P30AG21342).

Manuscript received August 20, 2004; revised manuscript received November 17, 2004, accepted November 22, 2004.

METHODS

Study design and sample. We conducted a qualitative study of 11 hospitals and their process improvement efforts

Abbreviations and Acronyms

ACC	= American College of Cardiology
AHA	= American Heart Association
AMI	= acute myocardial infarction
ECG	= electrocardiogram
ED	= emergency department
NRMI	= National Registry of Myocardial Infarction
PCI	= percutaneous coronary intervention
STEMI	= ST-segment elevation myocardial infarction

in the care of patients with STEMI who are treated with primary PCI. We selected hospitals based on their performance in time to acute reperfusion, using patient data from the National Registry of Myocardial Infarction (NRMI)-3 and -4 (8). To be eligible for our study, hospitals had to report at least 50 primary PCI cases during the two-year period January 2001 through December 2002. Because we were focused on top performance, we selected from these hospitals (n = 151) all hospitals with median door-to-balloon times of 90 min or less over their most recent 50 cases (n = 35). We then arrayed these 35 hospitals in order of their improvement in door-to-balloon time over the four-year period 1999 to 2002. Beginning with the most improved, we selected hospitals consecutively until we reached theoretic saturation (9,10). Theoretic saturation was deemed to occur when successive interviews and hospital visits did not generate any new process innovations or approaches that participants viewed as influencing door-to-balloon times. We selected among the top performers those hospitals with the most improvement so that we could elicit their views on what interventions had resulted in the faster times. All sampled hospitals agreed to participate.

We conducted one- or two-day site visits at each hospital (n = 11), which included in-depth interviews with staff (n = 122) identified by the hospital as substantially involved in improving the time to acute reperfusion for patients with STEMI. Staff included physicians, nurses, technologists, quality management personnel, and administrators from various departments including emergency services, cardiology, nursing, the cardiac catheterization laboratory, case management, quality management, and general administration. We used a standardized discussion guide with open-ended probes to conduct the in-depth interviews, which averaged about 1 h in length, as is standard for in-depth interviewing (11).

Data analysis. All interviews were audiotaped and transcribed by professional and independent transcriptionists to increase the reliability of interview data analyzed. Researchers with diverse clinical, public health, quality improvement, and management backgrounds conducted line-by-line review and coding of each transcript using the constant comparative method of qualitative data analysis (9,10,12) to identify common innovations in the door-to-balloon process described by participants at the 11 hospitals. Transcript coding was performed first independently and then in joint sessions of three or four researchers, including those who had conducted the site visit and two additional investigators (E.H.B. and T.R.W.). As is standard in qualitative analysis (10,13), the research team met periodically during the study to first articulate and then revise and refine the qualitative categories used in the coding process. This process included combining codes that initially overlapped and describing in more detail the kinds of data that would qualify for particular code assignments, as recommended for effective coding and analysis of qualitative data (10,13). For flow chart development, we used the sections of the transcripts that were coded as specific process designs that participants described at their hospitals. No single hospital fully exemplified the proposed approach to minimize preventable delays; rather, we extracted and coded what participants described as particularly effective process designs for reducing door-to-balloon times in their hospital, coding also what participants viewed as slowing the process. We synthesized these process designs into a single flow chart with benchmark time intervals based on our coding and analysis of participant interview data. We fed back the flow chart and benchmark times to participants for revision and comment, as is recommended (13,14) to enhance the validity of qualitative data analysis. All data were entered and analyzed using QSR 4 NUD*IST software (Sage Publications Software, Thousand Oaks, California).

RESULTS

Participants and hospitals. Key staff interviewed (n = 122) represented a broad range of physicians, nurses, technologists, quality management personnel, managers, and senior administrators (Table 1). The hospitals reflected a range of sizes, acute myocardial infarction (AMI) and PCI volumes, geographic locations, and teaching status (Table 2).

Table 1. Type of Staff Interviewed at Study Hospitals (n = 122)

Type of Staff	Number of Interviews
Physicians	
Emergency physicians	8
Cardiologists	15
Nurses	
Nurse managers	10
Cardiology case managers	4
Emergency department nurses	9
Catheterization laboratory nurses	11
Critical care unit nurses	3
Administrators	
Emergency department medical directors	7
Cardiology medical directors	2
Catheterization laboratory medical directors	3
Quality management directors/managers	9
Emergency medical services directors	3
Other directors, vice presidents, and presidents	20
Quality management staff	8
Other clinical/support staff	10
Total	122

Table 2. Description of Study Hospitals (n = 11)

ID	Region	Number of Beds	Teaching Status	Annualized AMI Volume*	Annualized PCI Volume*	Median PCI Time† (min)
1	Northeast	770	Teaching	925	63	85.5
2	Midwest	176	Teaching	202	27	75.5
3	South	870	Teaching	1,504	76	55.5
4	Midwest	426	Teaching	388	78	70.5
5	South	350	Non-teaching	623	88	69.0
6	West	204	Teaching	249	77	82.0
7	West	277	Teaching	240	25	89.0
8	South	633	Teaching	632	104	86.5
9	West	190	Non-teaching	386	38	89.5
10	West	111	Non-teaching	292	52	87.0
11	Midwest	276	Teaching	593	45	87.0

*Based on 2001 to 2002 volume. †Based on most recent 50 PCI cases in 2001–2002.
AMI = acute myocardial infarction; PCI = percutaneous coronary intervention.

The ideal process for timely acute reperfusion with primary PCI. The ideal process (Fig. 1) represents a synthesis of the best practices found in the sample of 11 hospitals and is not meant to reflect the specific process of any single hospital in the study. The door-to-balloon process for patients transported to the ED with a pre-hospital ECG performed and read by a paramedic before hospital arrival is depicted by Path #1 in Figure 1. The door-to-balloon process for patients arriving (by ambulance, car, or other method) without a pre-hospital ECG performed and read by a paramedic before hospital arrival is depicted in Path #2. For patients with a pre-hospital ECG indicating STEMI, the benchmark door-to-balloon time is 60 min (Fig. 2). For patients arriving

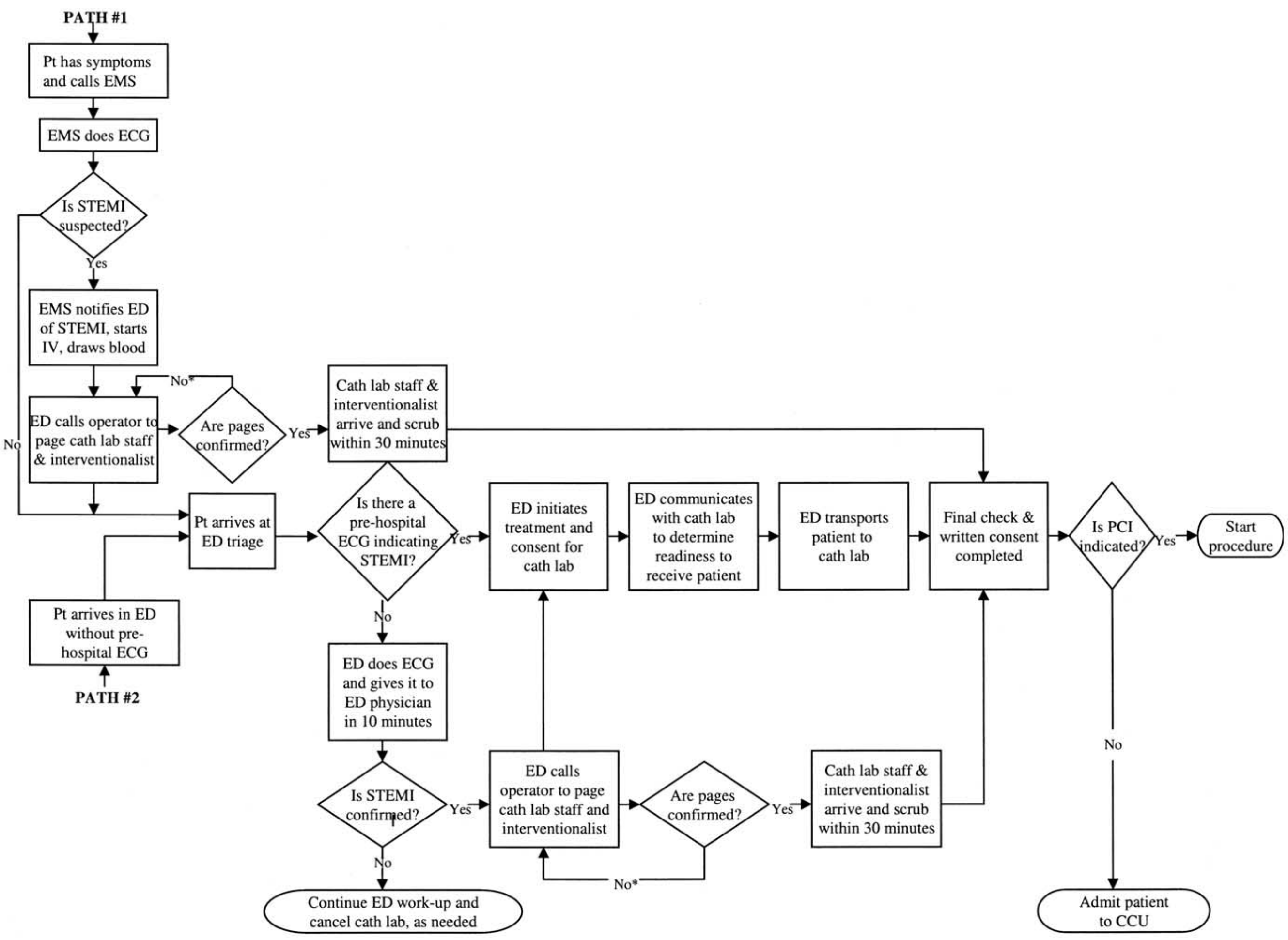

Figure 1. Flow chart for expediting acute reperfusion for patients with ST-segment elevation myocardial infarction (STEMI) treated with percutaneous coronary intervention. *If no response within 10 min, go to the next one on the on-call list. CCU = coronary care unit; ECG = electrocardiogram; ED = emergency department; EMS = emergency medical service; IV = intravenous; PCI = percutaneous coronary intervention; Pt = patient.

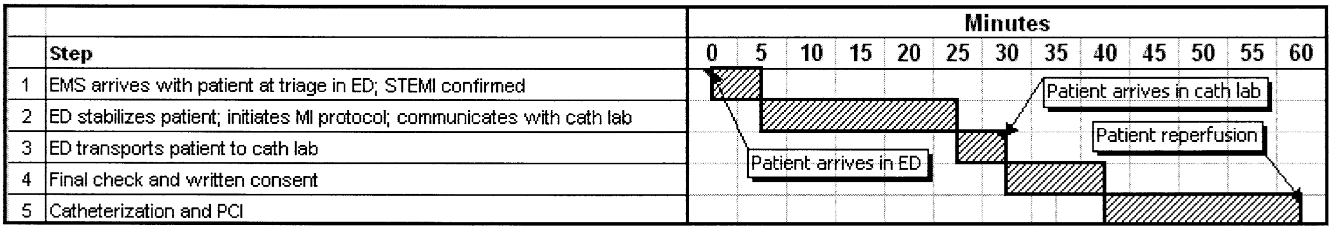

Figure 2. Path #1: steps and timeline for acute reperfusion: patients with pre-hospital electrocardiograms. MI = myocardial infarction; other abbreviations as in Figure 1.

without a pre-hospital ECG, the benchmark door-to-balloon time is 80 min (Fig. 3).

Path #1: when the patient is transported with paramedic and pre-hospital ECG. PRE-HOSPITAL ECG. The fastest median door-to-balloon times were achieved by hospitals with paramedics who performed ECGs in the field. As a result, we present this as an ideal approach. Thus, in Path #1, the paramedic performs and interprets a 12-lead ECG before hospital arrival, either before or during the transport. The paramedic notifies the ED of the ECG result, emphasizing when there is a suspected STEMI case. If possible, the ECG is transmitted to the ED. The paramedic, following standardized protocols, draws blood as needed, starts one or more intravenous lines, and administers aspirin or other treatments as appropriate.

ACTIVATION OF CATHETERIZATION LABORATORY. When the ED receives notice from the paramedic that the patient has a suspected STEMI, the ED calls the hospital operator, who immediately pages both the on-call catheterization laboratory staff and the on-call interventional cardiologist. The numeric page includes a prearranged signal (e.g., 911 after the page) to indicate the impending arrival of a patient with an acute STEMI. The team members rapidly confirm receipt of the page with the operator and urgently convene in the catheterization laboratory. If the pages are not confirmed by the team after 5 min, then another page is attempted. After 10 min without a response, the operator then pages the next person on the PCI on-call list. The list with the operator has at least one back-up person for each person on call. The catheterization laboratory staff and the interventional cardiologist are expected to be ready to start the procedure within 30 min of receiving the page.

ED PROCESS. Upon patient arrival in the ED, staff members follow a well-developed and agreed upon protocol for acute coronary syndrome, which specifies standardized practices for emergency triage, stabilization, and treatment of patients with possible STEMI. Based on the established protocol, patients with pre-hospital ECGs showing STEMI bypass the usual triage process, and the triage nurse quickly directs the patient to the ED and alerts the emergency physician. The emergency physician confirms diagnosis of STEMI and conducts a history and physical that focuses on the critical elements relevant for immediate treatment and eligibility for PCI. During this time, the emergency physician and nurses also initiate patient consent and, if time allows, prepare the patient for PCI according to joint protocols developed with the catheterization team. Before transport, the ED communicates with the catheterization laboratory staff to ensure the room is available and adequate staff members are present.

CATHETERIZATION LABORATORY PROCESS. The interventional cardiologist meets the patient at the catheterization laboratory and confirms STEMI diagnosis based on ECG, medical records, patient interview, and observations. Then the catheterization team members proceed through a final check of indications and contraindications, written consent is obtained or confirmed, and the patient is prepped for PCI. Ideally, the catheterization laboratory has been left prepared for the next procedure after the last procedure and the PCI can begin promptly.

Path #2: when the patient arrives in the ED without pre-hospital ECG. ED TRIAGE AND DIAGNOSTIC ECG. Some patients will arrive in the ED without a pre-hospital ECG. Consequently, we included a pathway for these

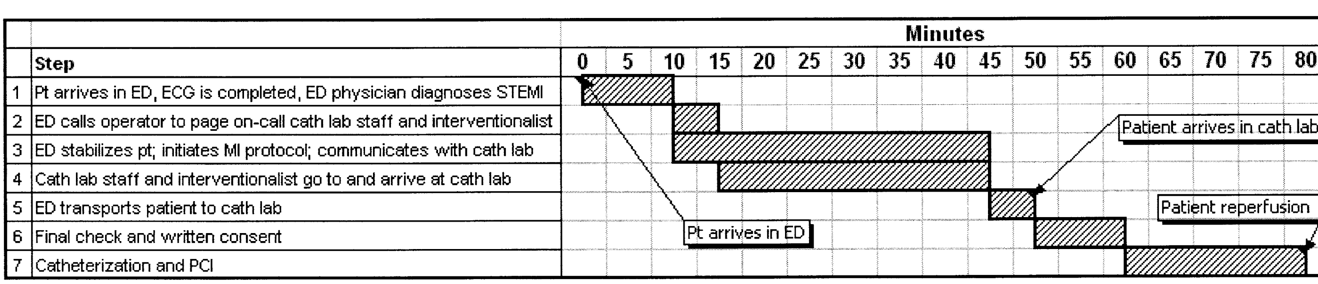

Figure 3. Path #2: steps and timeline for acute reperfusion: patients who arrive in the emergency department without pre-hospital electrocardiograms. Abbreviations as in Figures 1 and 2.

patients. In Path #2, in which there is no pre-hospital ECG, the ED triage nurse assesses patients for symptoms consistent with possible STEMI and implements the hospital's established acute coronary syndrome protocol. In cases of possible STEMI, the triage nurse directs appropriate staff to rapidly complete an ECG and show it to an ED attending physician to interpret immediately. If this physician diagnoses STEMI based on the ECG and available history and physical information, discovers no contraindications to PCI, and obtains verbal consent, he/she calls the operator to page both the catheterization laboratory staff and the interventional cardiologist, thereby activating the catheterization laboratory. Path #2 then follows the same process as Path #1 from this point forward.

DISCUSSION

On the basis of experiences of top-performing hospitals, we propose an ideal approach to reducing door-to-balloon times for patients with STEMI. The approach reflects a compilation of best practices in each step of the process, thereby creating a process in which hospitals can regularly achieve the 90-min door-to-balloon time standards set by the ACC/AHA in recent guidelines (6) for the treatment of STEMI. Although patient complexity and unique circumstances of the hospital might make the ideal process more difficult to achieve, we believe it can be used effectively to improve the quality of care for patients with STEMI who receive primary PCI.

A critical part of the process is the rapid acquisition and interpretation of the ECG. This task sets the process in motion. Ideally, before the patient arrives in the ED, this information is obtained and transmitted by paramedics to the ED. This process enables earlier notification of the on-call catheterization laboratory staff and interventional cardiologist and thus can reduce delays in waiting for the catheterization team to be ready to receive the patient. Previous research has demonstrated that pre-hospital ECGs can reduce door-to-balloon times substantially (15). In addition, without pre-hospital ECGs, patients with atypical presentations may be delayed at the ED if triage nurses do not recognize the need for an immediate ECG. Nevertheless, having an effective pre-hospital ECG program in place requires substantial investment by the hospital, emergency physicians, and the emergency medical services in the area. Achieving this best practice requires adequate paramedic staffing of emergency vehicles, availability of 12-lead ECG equipment in emergency vehicles, extensive training of paramedics to interpret 12-lead ECGs, and ongoing communication and feedback between paramedics and emergency physicians to ensure necessary trust in paramedic ECG interpretations by emergency physicians in the hospital.

Another central aspect of the ideal process is the rapid activation of the catheterization team by emergency physicians, rather than by cardiologists. The best practices include assigning the emergency physicians responsibility for deciding to call in the catheterization team. This practice circumvents the delay in contacting a cardiologist, who would then need to obtain and review patient data for a decision. Further, in cases where a pre-hospital ECG is available, having the emergency physicians activate the catheterization team allows for parallel processing. The catheterization team can be mobilized to open, if needed, and prepare the catheterization laboratory while the patient is being transported to and stabilized in the ED, reducing door-to-balloon time substantially.

Despite evidence that emergency physician activation of the catheterization team can significantly reduce door-to-balloon time (16), establishing this best practice requires substantial effort and interdisciplinary trust and communication. Physicians and hospitals that implement this practice must recognize that there will be "false starts" in which emergency physicians activate the catheterization team and the procedure is canceled at some point later in the process. In our study of top-performing hospitals, staff reported that false starts happened rarely and were accepted as an inevitable consequence of minimizing door-to-balloon times.

The process design and benchmark door-to-balloon times we propose are based on the views of key staff involved in improvement efforts at a limited number of hospitals. Further, hospitals were selected on the basis of door-to-balloon times for patients in the NRMI database, and additional studies of top-performing hospitals using alternative door-to-balloon data would be helpful. However, the study did include a broad range of teaching and non-teaching hospitals from different geographical regions and with varying AMI volumes. In addition, although the qualitative study design is ideally suited to describing complex processes (12,13,17), we do not have quantitative measures of each innovation to assess its statistical association with door-to-balloon times. However, we used state-of-the-art qualitative methods recommended (13,14,18) to improve the reliability and validity of our findings, including consistent use of the discussion guide, audio taping and independent transcription of open-ended interviews, detailed documentation of coding decisions, joint coding and analysis of all transcripts by a multidisciplinary team of researchers, and feedback of our results to the participants for review.

This study provides guidance to hospitals that aim to achieve outstanding performance in door-to-balloon times for patients with STEMI. By synthesizing information from hospitals that regularly meet the 90-min door-to-balloon guidelines, we propose an ideal process design, which can facilitate better performance in the care of patients undergoing primary reperfusion with primary PCI. Although we have focused mainly on specific processes, it is essential that these processes be supported by the organizational culture. As we have noted in previous work in the area of increased beta-blocker use (19), performance improvement requires administrative support, clinical leadership, shared goals, and effective data feedback. The present study describes specific systems improvements that enable reductions in door-to-balloon times. However, achieving the recommended best practices will likely require substantial organizational commitment and leadership, extensive interdisciplinary collaboration, and effective strategies for overcoming barriers to organizational change.

Reprint requests and correspondence: Dr. Harlan M. Krumholz, Yale University School of Medicine, 333 Cedar Street, P.O. Box 208088, New Haven, Connecticut 06520-8088. E-mail: harlan.krumholz@yale.edu.

REFERENCES

1. Berger PB, Ellis SG, Holmes DR Jr., et al. Relationship between delay in performing direct coronary angioplasty and early clinical outcome in patients with acute myocardial infarction: results from the Global Use of Strategies to Open Occluded Arteries in Acute Coronary Syndromes (GUSTO-IIb) trial. Circulation 1999;100:14–20.
2. Cannon CP, Gibson CM, Lambrew CT, et al. Relationship of symptom-onset-to-balloon time and door-to-balloon time with mortality in patients undergoing angioplasty for acute myocardial infarction. JAMA 2000;283:2941–7.
3. Rogers WJ, Canto JG, Barron HV, Boscarino JA, Shoultz DA, Every NR. Treatment and outcome of myocardial infarction in hospitals with and without invasive capability. Investigators in the National Registry of Myocardial Infarction. J Am Coll Cardiol 2000;35:371–9.
4. Burwen DR, Galusha DH, Lewis JM, et al. National and state trends in quality of care for acute myocardial infarction between 1994–1995 and 1998–1999: the Medicare health care quality improvement program. Arch Intern Med 2003;163:1430–9.
5. Angeja BG, Gibson CM, Chin R, et al. Predictors of door-to-balloon delay in primary angioplasty. Am J Cardiol 2002;89:1156–61.
6. Ryan TJ, Antman EM, Brooks NH, et al. 1999 update: ACC/AHA guidelines for the management of patients with acute myocardial infarction. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Acute Myocardial Infarction). J Am Coll Cardiol 1999;34:890–911.
7. Eppen E, Gould F. Introductory Management Science. Englewood Cliffs, NJ: Prentice Hall, 1984.
8. French WJ. Trends in acute myocardial infarction management: use of the National Registry of Myocardial Infarction in quality improvement. Am J Cardiol 2000;85:5B–9B, discussion 10B–2B.
9. Strauss A, Corbin J. Basics of Qualitative Research, Grounded Theory Procedures and Techniques. London: Sage Publications, 1990.
10. Miles MB, Huberman AM. Qualitative Data Analysis: An Expanded Sourcebook. 2nd edition. Thousand Oaks, CA: Sage Publications, 1994.
11. McCracken G. The Long Interview. Newbury Park, CA: Sage Publications, 1988.
12. Pope C, Mays N. Reaching the parts other methods cannot reach: an introduction to qualitative methods in health and health services research. BMJ 1995;311:42–5.
13. Patton MQ. Qualitative Evaluation and Research Methods. 3rd edition. Newbury Park, CA: Sage Publications, 2000.
14. Mays N, Pope C. Rigour and qualitative research. BMJ 1995;311:109–12.
15. Canto JG, Rogers WJ, Bowlby LJ, French WJ, Pearce DJ, Weaver WD. The pre-hospital electrocardiogram in acute myocardial infarction: is its full potential being realized? National Registry of Myocardial Infarction-2 Investigators. J Am Coll Cardiol 1997;29:498–505.
16. Thatcher JL, Gilseth TA, Adlis S. Improved efficiency in acute myocardial infarction care through commitment to emergency department-initiated primary PCI. J Invasive Cardiol 2003;15:693–8.
17. Glaser B, Strauss A. The Discovery of Grounded Theory: Strategies for Qualitative Research. Chicago, IL: Aldine Publishing Company, 1967.
18. Popay J, Rogers A, Williams G. Rationale and standards for the systematic review of qualitative literature in health services research. Qual Health Res 1998;8:341–51.
19. Bradley EH, Holmboe ES, Mattera JA, Roumanis SA, Radford MJ, Krumholz HM. A qualitative study of increasing beta-blocker use after myocardial infarction: why do some hospitals succeed? JAMA 2001;285:2604–11.

APPENDIX

Please see the online version of this article for the Acknowledgments and Discussion Guide.